berta
ur
ourn

[Misc pubns]
1981-23

NOISE IN THE WORKPLACE

Alberta
ENVIRONMENT COUNCIL OF ALBERTA

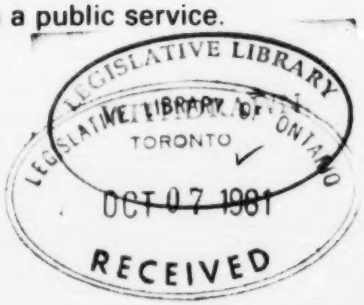
1-1

NOISE IN THE WORKPLACE

January 1981

Prepared by
John Throckmorton
Occupational Health and Safety Division
Alberta Workers' Health, Safety and Compensation

Distributed without charge as a public service.



Copies of this
report may be obtained
upon request to

Environment Council of Alberta
2100 College Plaza Tower 3
8215–112 Street
Edmonton, Alberta
T6G 2M4

Tel.: (403) 427-5792

ECA80-16/IB2

Preface

During province-wide public hearings, the Environment Council of Alberta is offering everyone an opportunity to express their views and opinions on noise in Alberta. This information will be used to help the Council advise the Government of Alberta on future programs to deal with noise. In preparing for the hearings, the Environment Council has published a series of bulletins and brochures to improve the information base on several noise topics.

This bulletin discusses in detail noise in the industrial setting. It describes some characteristics of sound and its measurement, noisy occupations, hearing-protection programs, legislation and other aspects. The report was prepared by the Occupational Health and Safety Division of Alberta Workers' Health, Safety and Compensation at the request of the Environment Council.

Although the Council has published this report, the views expressed are those of the author and not necessarily those of the Council. The Council is not responsible for any facts or opinions presented or implied herein. What the Council does endorse is that the points raised are important and should be considered by Albertans when discussing noise. It is hoped the reader will find the information contained in this bulletin useful in preparing for the hearings.

Figure 7. Circumaural protector – hard hat with earmuffs. 7
Figure 8. Example of the use of a circumaural protective hard hat with earmuffs 7
Figure 9. Insert hearing protectors 8
Figure 10. Sample of an audiogram 10
Figure 11. An audiometer 11
Figure 12. A sound booth and audiometer. 12
Figure 13. Audiogram showing progession of noise-induced hearing loss 14
Figure 14. Contours showing maximum sound pressure levels 16

INTRODUCTION

WHAT IS NOISE

Noise is defined as any unwanted sound. In other words, one person's music can be noise to another. This publication deals with unwanted sound within the industrial setting. Industrial noise tends to fall within a given range of frequencies and is generally considered loud. The loudness of the noise often results in hearing loss to the unprotected worker.

NOISE AS AN OCCUPATIONAL HAZARD

Noise is considered to be a major cause of all hearing loss. Although noise may not always be the leading cause of a hearing handicap, it frequently can be a contributing factor. For example, a hearing loss resulting from aging, together with that from exposure to noise, may ultimately lead to a greater handicap than would be the case for simply a hearing loss due to aging alone. The terms "hearing handicap" and "hearing loss" are described more fully in Section 5.

Traditionally, it has been estimated that 10 percent of Alberta's work force is exposed to occupational noise considered hazardous to hearing. This would amount to 125,000 workers, a number that may well be a conservative estimate at this time. Also, these figures do not take into account one of the largest segments of Alberta's work force, the farmer, whose number is estimated at 60,000. Occupational noise, therefore, is the most common and prevalent health hazard in the workplace.

Although noise is not a lethal agent, does not cause serious illness, and does not maim, in a disfigurement sense, it can cause a significant handicap in later years, more so than most people imagine. Significant loss of hearing can be as debilitating as some of the more spectacular health and safety hazards with much shorter latency periods. Like most known health and safety hazards, unfortunate consequences of noise-induced hearing loss can be, and are being, prevented.

HEARING CONSERVATION WITHIN INDUSTRY

A formalized effort to preserve hearing of workers in the workplace is commonly referred to as an occupational hearing conservation program. The Government of Alberta has for some time actively promoted occupational hearing conservation within the province's industries. The agency responsible for this program is the Medical Services Branch of the Occupational Health and Safety Division which in turn is a part of Alberta Workers' Health, Safety and Compensation. It should be understood, however, that the Division is not part of the Workers' Compensation Board (WCB).

In order to initiate a hearing conservation program, the degree of hazard must be assessed. Two rules of thumb for excessive noise are generally cited. First, if people cannot communicate easily within arm's length of each other, the noise within the area of conversation is likely excessive. Second, if after exposure to noise, the ears ring, feel plugged, and speech and other environmental sounds seem muffled, overexposure to noise has likely occurred. The next logical steps are to identify and locate the sound source, measure the intensity (loudness) of that sound, and finally calculate the actual length of time an individual would be exposed to that sound. The basic steps of an occupational hearing conservation program are listed below. These steps will be expanded throughout this bulletin.

1. Identify, Locate, And Measure Sound.
2. Use Engineering Methods To Reduce Sound To Acceptable Levels Or As Close To Acceptable Levels As Possible Within Current Technology.
3. Implement Personal Protection Of The Worker When Sound Cannot Be Reduced At Source, Along The Pathway, Or When The Worker Cannot Be Isolated Effectively. Such Steps Include:
   a. Personal Hearing Protectors;
   b. Audiometric Monitoring,
   c. Worker Education;
   d. Posting Of Work Areas as Hazardous To Hearing;
   e. Administrative Controls.

depict? Actually, intensity is related to a power which is expressed as watts per square centimetre. In acoustics, sound is measured by the pressure it exerts on the diaphragm of a microphone. A dB is a ratio between a given sound pressure and an established reference sound pressure.

Pressure is measured in units called newtons. The value of the smallest acoustical pressure which is barely audible to the average, young, normal ear at 1,000 Hz is 0.00002 newtons per square metre (N/m^2) and is consequently the reference sound pressure which equals zero dB sound pressure level (dB SPL). The point of discomfort for the human ear is commonly cited at 20 N/m^2 (120 dB SPL). This range corresponds to a ratio of 1 to 1,000,000. Since interest in acoustics, particularly audiometry, centres on rather small changes in pressure, a scale other than linear had to be developed. For example, a linear ruler covering such a ratio as human hearing would need to range from one inch to 16,000 miles, a rather impractical tool. The dB, therefore, is not linear but logarithmic. The base power for intensity is a log of 10 which means an increase of 10 dB. Table 1 depicts the relationship between decibels and relative energy intensity. Interestingly enough, a sound of 40 dB sounds twice as loud as 30 dB but is much more intense - another noteworthy difference between intensity and loudness.

Since the dB is a logarithmic scale, it cannot be added to or subtracted from directly. For example, 30 dB SPL plus 30 dB SPL does not equal 60 dB SPL, rather it equals 33 dB SPL despite the fact that the sound energy has been doubled. This explains why reducing noise to acceptable levels through engineering is such a major undertaking. To reduce a noise from 100 dB SPL to 97 dB SPL (on the A scale) is to reduce the energy level by half and yet 3 dB would seem an insignificant improvement.

A final analogy is presented to emphasize the fantastic sensitivity and range of the human ear with respect to intensity. The reference sound pressure value of 0.00002 N/m^2 is a very difficult dimension with which to identify; it is a very small

TABLE 1

The Relationship between Decibels and Relative Energy Intensity

Relative Energy Intensity	Decibels	Loudness
100,000,000,000,000	140	Jet Aircraft
10,000,000,000,000	130	Threshold of Pain
1,000,000,000,000	120	
100,000,000,000	110	
10,000,000,000	100	Inside Propellor Aircraft
1,000,000,000	90	
100,000,000	80	Auto at high speed
10,000,000	70	
1,000,000	60	Conversation
100,000	50	General Office
10,000	40	Private Office
1,000	30	Bedroom
100	20	
10	10	
1	0	

pressure or energy value. Were a reader to drop one page of this bulletin to the table from a height of 1 centimetre, the energy released, were it converted to sound energy, would be sufficient to keep him hearing a 1,000 Hz tone for the rest of his life.

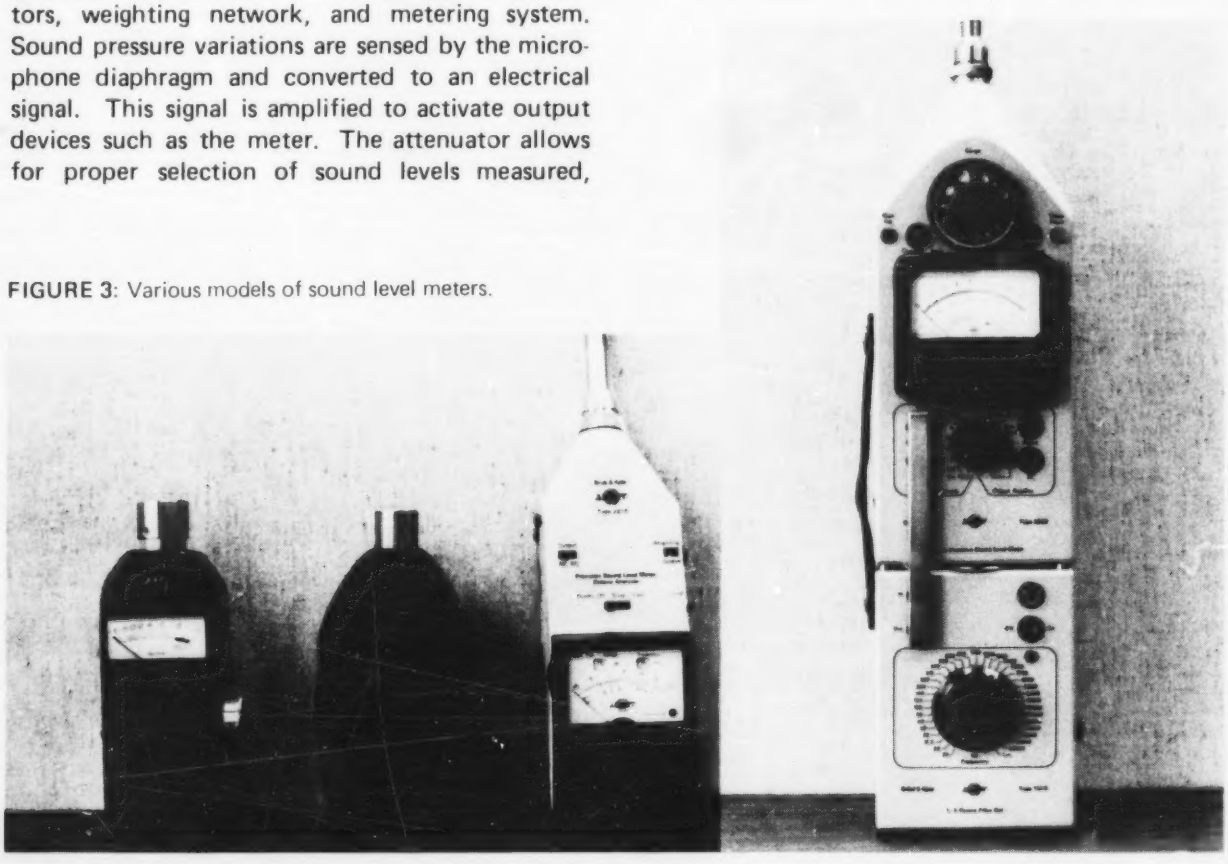
SOUND MEASURING DEVICES

The equipment available to measure sound includes sound level meters (SLM), frequency analyzers, impulse noise meters, oscilloscopes, and noise dosimeters to mention a few. The basic measuring instrument, the sound level meter, is singled out for discussion. The noise dosimeter will also be discussed briefly.

Figure 3 shows three types of sound level meters presently on the market. The basic elements of a meter include the microphone, amplifier, attenuators, weighting network, and metering system. Sound pressure variations are sensed by the microphone diaphragm and converted to an electrical signal. This signal is amplified to activate output devices such as the meter. The attenuator allows for proper selection of sound levels measured, usually in 10 dB increments. The weighting networks are merely electrical circuits that filter the signal and serve to discriminate against certain frequencies.

The weighting networks include A, B, C, and sometimes D response curves as illustrated in Figure 4. Differences in these networks are primarily in their sensitivity to lower frequencies, the A-weighted scale being the most biased against low frequency. After the electrical signal from the microphone has passed through the amplifier, attenuator, and appropriate weighting network, the meter displays a value that is proportional to the signal. That value is scaled in dB SPL. The meter may be operated on either fast or slow response depending on the type of noise being measured.

FIGURE 3: Various models of sound level meters.



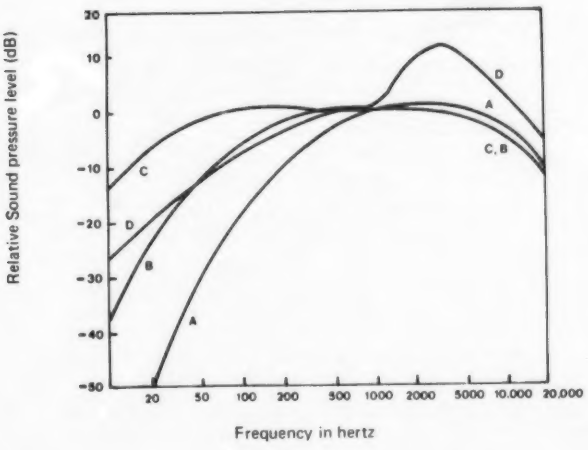


FIGURE 4: Weighting network frequency response curves for a sound level meter.

There are basically four types of sound level meters, types 1 through 3, and type S. A meter is categorized into a given type based upon its accuracy and performance capability. In order to be classed as a sound level meter under the American National Standard Institute (ANSI) S 1.4 1971, the instrument must measure the root mean square (rms) level of sound pressure, meet rigid specifications of smoothness of response, linearity, and attenuation accuracy, and have a weighting network.

A sound level meter only measures sound at a given point in time. It does not provide a sum of exposure over a specified period. Though it is possible to estimate a worker's exposure based on a time and motion study and sound levels present, it is frequently convenient to use a noise dosimeter. This instrument is particularly useful for those workers who are mobile and subjected to a variety of noise levels throughout the working day.

Common types of dosimeters are pictured in Figure 5. The dosimeter's microphone is attached as close as possible to the wearer's ear. The electrical signal from the microphone is transmitted to the integrating unit located either in the wearer's pocket or belt. The integrating unit accumulates sound energy over a specified period and indicates when a person has exceeded the allowable dosage, much like a radiation dosimeter. Other instruments

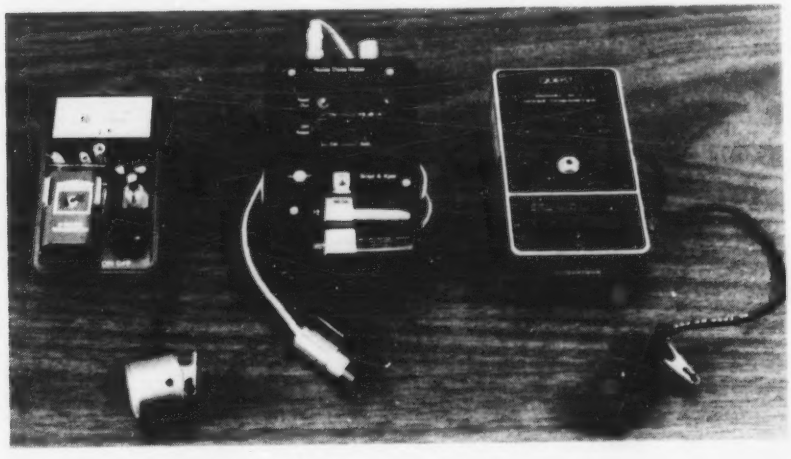


FIGURE 5: Three types of dosimeters.

calculate the average sound level over a given period. In any case, the read-out device can be located in the individual unit or in a separate dosage indicator to which the individual unit is plugged at the end of the period.

Dosimeters seem to be quite an appealing method of solving questionable dosages. They are not, however, the panacea envisioned. Dose studies are time consuming and tedious to administer. Dosimeters frequently do not perform well in cold weather and have limited capability in impact or impulse noise situations. With respect to the latter problem, the circuitry is not capable of accurately recording such a rapid variation in pressure. This also is a problem with the sound level meter.

THE A SCALE

The most common method of measuring noise is through the use of an A-weighted scale (Figure 4). This notation is usually abbreviated dBA. Historically, sound levels were measured in linear or unweighted fashion. In order to ascertain their significance, the sound in question was broken down into bands of frequencies. It was recognized early, however, that noise within certain frequency bands is more hazardous than others, the linear dB value by itself being an insufficient measure. An easier method was needed to simplify the measuring process. In an effort to achieve this, three weighting scales were developed and today are commonly found on sound level meters.

Initially, it was felt that the A scale simulated the ear's sensitivity to those sounds below 65 dB. The B scale simulated the ear's sensitivity to those sounds between 65 and 85 dB, and the C scale simulated those sounds above 85 dB. However, it was determined subsequently that the A scale was as good an indicator of hazardous noise as any of the other scales and correlated fairly well with people's subjective impressions of the noise in question. Therefore, the A-weighted method of sound measurement has been in effect since the early 1970s.

Although the A-weighted value is a good description of sound, it is not perfect. For example, it is not a good indicator of a human response to sound with intense low frequency components or a noise with tonal components superimposed over a sound. Also, the A-weighted scale is not used to measure impact or impulse noise such as metal banging on metal or a rifle shot. The impulse noise meter is the preferred method to measure such a noise. If a sound level meter is used, impact and impulse noise is measured utilizing the C scale on fast response. This only gives a general idea of the level. Figure 6 depicts A-weighted sound levels commonly found within industries.

FIGURE 6: A-weighted sound levels commonly found within industry.

NOISY OCCUPATIONS IN ALBERTA

Many occupations and industries in Alberta have noise levels considered hazardous to hearing. Those involving the highest noise levels in terms of both sound level and potential exposure are:

1. Construction and Road Building
   a. Heavy Equipment Operators
   b. Power-Actuated Tools
2. Natural Resource Industries
   a. Oil Well Drilling
   b. Mining
   c. Saw Mills
   d. Woodland Operations (Timber Harvest)
3. Steel Fabrication
   a. Boiler Making
   b. Drop Forge Operators.

Appropriate engineering to reduce noise generated at source is the most effective method to control noise in the workplace. Quieter machinery means a quieter working environment. Noise can also be controlled by blocking the noise pathway to the workers. If these two methods are not possible, workers can be provided with personal hearing protectors. Controlling noise at source or along the pathway is essentially an engineering application and, therefore, beyond the scope of this bulletin.

HEARING PROTECTORS

TYPES OF PERSONAL PROTECTIVE DEVICES AVAILABLE

When all efforts have failed to reduce occupational noise exposure to a safe level, workers must be protected directly. A wide variety of personal protective devices is available on the market. This can be bewildering to the prospective consumer who is aware there is more to hearing protection than plugging the ear.

Hearing protectors fall into three categories; circumaural, aural insert, and enclosure (earmuffs, plugs, and a helmet, respectively). Sound helmets are not commonly found within industry and are reserved for extremely high noise levels.

The maximum attenuation or sound reduction that can be achieved with muffs, plugs, or a combination thereof is 50 dB. This is because sound can be transmitted to the nerves of the inner ear by bone conduction. For example, if a vibrator that produces a tone (single frequency) is held against the teeth, that tone is heard clearly. By using earmuffs together with a helmet, an additional 10 dB (60dB total) of sound reduction is gained as the bones of the head are covered.

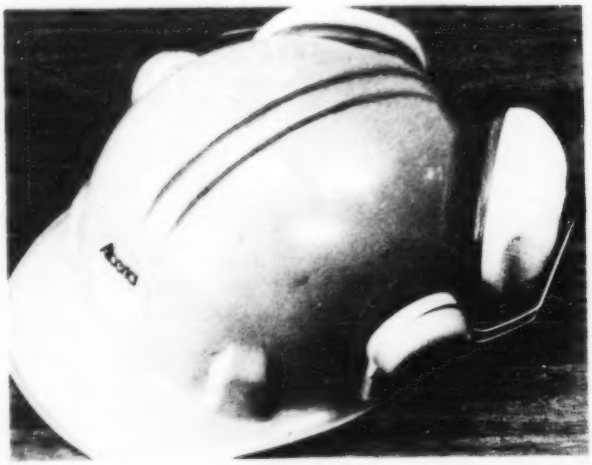


FIGURE 7: Circumaural protector - hard hat with earmuffs.

FIGURE 8: Example of the use of a circumaural protective hard hat with earmuffs.

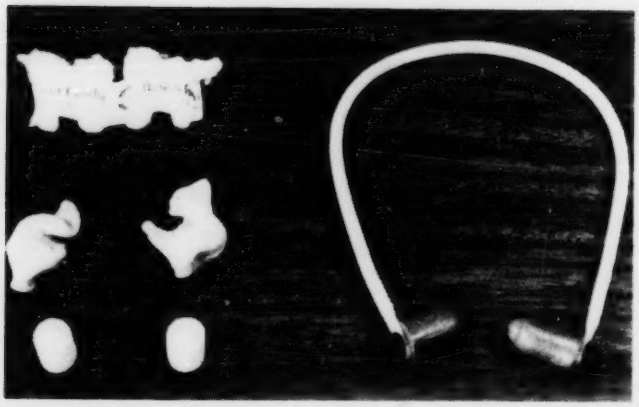


FIGURE 9: Insert hearing protectors.

Figures 7, 8, and 9, show various insert and circumaural protective devices. Earmuffs are dome-shaped cups that fit over the ears. The cups are held in place by a spring-type suspension assembly placed over or behind the head, under the chin, or attached to a safety hard hat depending upon the type of assembly. Air, foam, or liquid-filled cushions fit onto the domes and provide an acoustical seal between the head and dome. The suspension assembly must provide sufficient force to ensure a good seal.

Several sub-categories are found among earplugs or inserts; premoulded, custom, and formable. The premoulded plug comes in various sizes and must be fit to the ear much like a pair of shoes to the feet. The plugs are frequently flanged, examples of such types being the Sound Silencer and V-15-R. The custom plugs are made specifically for the individual. Using a mixing compound, an impression is made of the outer ear and some portion of the ear canal. The impression is then sent to the manufacturer who makes the protector from that impression. The protector is frequently a soft plastic and may be vented. The procedure for making a custom plug is much the same as for hearing-aid moulds. The formable type earplug is rolled into a conical shape at the end and inserted into the ear, the plug expands, fitting itself to the contour of the ear canal. Deci-damp, EAR, and Bilsom Propp-O-Plast are examples of formable plugs widely used in Alberta. Formables are usually discarded after use although some types can be washed and reused several times.

The circumaural style of hearing protector is more exotic, and is referred to as an hearing-aid protector. These devices are used with high noise levels where accurate speech reception is required. The device has a radio receiver built into the dome. Music or messages can be delivered from a central transmitter. The hearing-aid protectors can be AM, FM, Line, or on a loop system. Some of these devices are direct descendants of auditory training systems used in educational settings for the deaf. The dome must attenuate the noise sufficiently to allow the communication headset to be used at a level which itself is not a hazard to hearing. This problem is a difficulty with commercial radio headsets which were not designed for occupational noise situations. These type of headsets reportedly have been used on work sites and their use is discouraged. Needless to say, hearing-aid protectors are relatively expensive and appropiate for only specialized situations.

EARMUFFS VERSUS EARPLUGS VERSUS CUSTOM MOULDS

Each type of protector listed above has its relative advantages and disadvantages depending upon the work situation and noise levels encountered. Earplugs are quite popular in the workplace. Many experts feel they are as good as muffs because theoretically, some plugs offer as much protection as the more cumbersome earmuffs. Earplugs are easily carried, stored, maintained, initially the most economical, and reportedly the most comfortable. Comfort is a key to worker acceptance of a hearing protector. Also, glasses and long hair do not interfere with their use.

On the other hand, muffs are less likely to be worn improperly. For example, loss of attenuation due to improper muff seal as opposed to an improper plug seal likely will not be as significant. Earplugs, particularly premoulded, lose their seal due to jaw movement and must be reseated. Muffs,

therefore, are more convenient to use, more hygienic, easy for supervisors to monitor, and probably no less comfortable than plugs. Frequently, plugs are felt to be more comfortable because they are improperly sealed in the ear. Over the long term, earmuffs are as economical as disposable plugs.

Custom plugs offer the advantages of individual fit, sense of personal ownership, and economy over the long term. The plug impression must be taken properly, however, and frequently the dimensions of the ear canal will change, leading to acoustic leaks. Custom plugs with vents are popular with workers because the sense of fullness that occurs when the ears are plugged is absent. Better speech communication seems to occur in all environments than with conventional protectors. The effectiveness of these devices is controversial. Some acoustical experts feel that too much low and mid-frequency noise is allowed to filter through. The cost for vented plugs is rather high and probably not attractive to industries where worker turnover is rapid.

PROBLEMS WITH HEARING PROTECTION IN THE WORKPLACE

Problems with hearing protection in the workplace fall into two basic categories, worker resistance and protector performance under field conditions. Of the two, the latter may be the more serious. Excuses for workers not wanting to wear hearing protectors include "I can't hear my machine, I can't hear safety sounds, I can't hear others, they are too hot, you get used to the noise, I'm too old, ad nauseam . . . . "Most of the excuses are unfounded and will not replace lost hearing.

First, a person does not get used to noise, rather he goes deaf. Second, if a warning sound is heard over the noise it will be heard when the protector is worn because the protector simply reduces noise, it does not eliminate it. Therefore, the warning signals should still be audible. The same applies to audible idiosyncracies of a machine. The only qualification to this argument is that some period of adjustment to attenuated sound may be required. In any case, how does one propose to hear warning and operational sounds if hearing loss due to excessive noise develops?

Third, the claim of not being able to understand others when wearing protectors is frequently unjustified although circumstances may arise when a germ of truth to that claim exists. Theoretically, speech will be heard better in high noise levels, particularly where reverberation exists, when protectors are worn. With hearing protectors, the ear is no longer driven to distortion due to the high noise level and reverberation will be reduced thus making the speech signal clearer. In lower noise levels, however, problems can occur particularly if the protector chosen is overprotective to that environment. Workers with significant hearing loss will encounter more problems than their counterparts with normal hearing. Care must be exercised in selecting proper hearing protectors in terms of attenuation and the frequency response curve of that attenuation.

In order to determine if the use of hearing protectors poses a safety hazard to a hearing-impaired worker or his fellow workers, the environment, warning signal, protectors to be used, and worker's hearing must be carefully evaluated. An acoustical expert, physician, and a neutral worker (safety expert perhaps) thoroughly familiar with the operation in question should be involved in such a determination.

The fact that protectors are sometimes uncomfortable is undeniable, and is frequently the cause of their rejection. All other reasons are simply excuses. Basically, the higher the noise level the better that workers will accept hearing protection.

The area of field performance is a serious concern. Both the American National Standards Institute (ANSI) (S. 3.19-1974) and the Canadian Standards Association (CSA) (Z. 94.2-1974) have published standards to which hearing protectors should adhere. CSA, in addition to attenuation evaluation, has specific labelling and durability requirements. There are differences between the standards in attenuation evaluation. CSA follows the earlier,

and somewhat less realistic ANSI technique of attenuation evaluation. Nevertheless, neither the current ANSI or CSA standard offers a technique for evaluating the attenuation characteristics of the given protector that sufficiently duplicates field usage. A jury of 10 subjects is carefully fitted and evaluated in a laboratory environment.

In actual field conditions, workers use the protection with minimal supervision. A recent study on earplug-type protectors used in the workplace showed that an average of 33 to 50 percent of their effectiveness was lost due to improper wearing by the 168 workers sampled. In fact, the rule of thumb for hearing protection attenuation is 10 dB under actual field conditions, a far cry from laboratory data which can indicate up to 25 dB to 30 dB depending upon the protector. This is simply due to improper wearing and maintenance of hearing protectors. Consequently, use of both earplugs and ear muffs is commonly recommended for noise levels in excess of 105 dB SPL.

Given that workers resist wearing hearing protection and that protectors may have limited effectiveness when improperly worn or maintained, what is an employer to do in order to carry out his responsibilities of preventing an occupational disease? This brings us to audiometry, the heart of a hearing conservation effort. Audiometry, frequently looked upon with disdain by some industries due to potential cost, is a tool which can contribute much towards solving the employer's dilemma.

AUDIOMETRIC PROGRAM

THE AUDIOGRAM

The audiogram (Figure 10) is simply a graphic representation of an individual's hearing sensitivity. The horizontal axis shows frequencies increasing in octave intervals from left to right, an octave being a multiple of two. The frequencies of 3,000 Hz, 6,000 Hz, and on some audiograms, 1,500 Hz, are

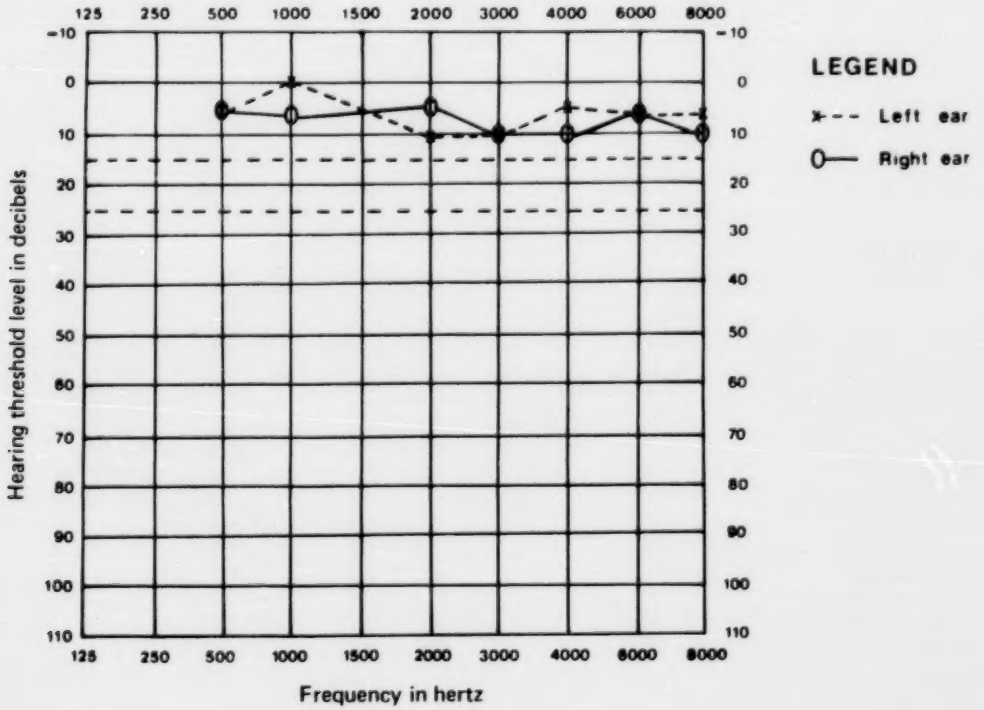


FIGURE 10: Sample of an audiogram.

FIGURE 10
Sample of an Audiogram

not octave intervals. The vertical axis shows decibels at 10 dB intervals beginning at zero or minus 10 dB. The dB on the audiogram and dB SPL are not the same. The zero on the audiogram, or audiometric zero, was established by deriving a median value from a population sample. This allows for the differential auditory sensitivity of the ear, as described earlier, and establishes a straight horizontal line across the audiogram. For example, audiometric zero at 1,000 Hz is 7 dB SPL and audiometric zero at 250 Hz is 24.8 dB SPL. Since the ear is less efficient in the lower frequencies, more dB SPL intensity is required to achieve zero. These base values, however, depend on which standard is being utilized: that is, American Standards Association (ASA), International Standards Organization (ISO), or ANSI. ASA is largely obsolete and was significantly different from ANSI and ISO due to population sampling methods. The decibel value on an audiogram is referred to as dB hearing level (HL) in order to distinguish it from dB SPL.

When hearing is tested, an attempt to establish threshold is being made. Threshold is defined as the level at which the individual can barely hear the test tone at least 50 percent of the time. The threshold, therefore, represents the difference between an individual's hearing and the median value or audiometric zero. This result is properly termed hearing threshold level (HTL). Hearing acuity for adults is considered normal for any given frequency if the HTL is 25 dB or better. This does not mean, however, that the ear is necessarily free of auditory disease.

The device used to test hearing is an audiometer (Figure 11). Audiometers used in occupational settings are relatively simple compared to the equipment utilized within the clinical setting, where much more detailed testing is required. The audiometer is a pure tone oscillator with frequency and intensity controls.

The signal is fed to receivers or headphones placed over the ears. From an engineering standpoint, the headphones are the key component of an audiometer. They must be handled with care, and periodically calibrated. Audiometric zero is built into the audiometer using ISO or ANSI reference values.

FIGURE 11: An audiometer.

Hearing testing should be conducted in a relatively quiet area. It is possible to find ordinary rooms that, on a given day, will be quiet enough to meet provincial standards. Figure 12 shows a commercially available test booth adequate for occupational hearing tests. It has proven cheaper to buy commercial booths rather than custom build them.

Some misunderstanding frequently occurs regarding sound booths being soundproof. Sound booths are highly dampened inside and give a sense of "deadening quiet". There is a limit to their attenuation value, the low frequency interference being part-

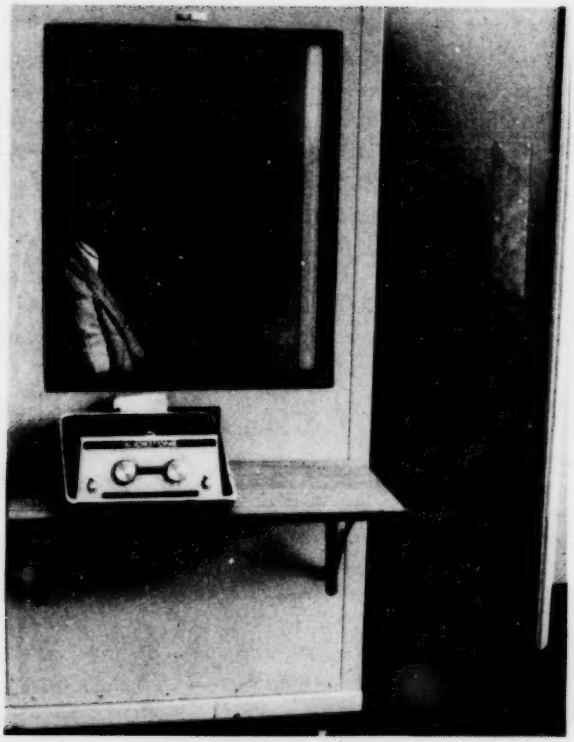


FIGURE 12: A sound booth and audiometer.

icularly difficult to eliminate. A sound booth, therefore, should not be placed in the middle of the shop floor. The fact that sounds are audible within a test room or booth does not mean the area is unsuitable for testing. Sounds can be present which lie outside the frequency range of concern. Admittedly, the existence of such extraneous or ambient noise does not create a favourable impression and such situations should be avoided.

When thresholds are recorded onto the audiogram, the right ear results are identified with a red O and the left ear is identified with a blue X (Figure 10). The recorded HTL's are frequently referred to as pure tone air conduction thresholds as opposed to bone conduction or speech reception thresholds. Pure tone air conduction thresholds by themselves will not aid a medical practitioner in diagnosing auditory disease. More detailed testing is required. Pure tone thresholds will reflect a change in hearing from one test to the next and provide information as to whether auditory acuity deviates from the norm at any given frequency. Most importantly, pure tone thresholds will identify the effects of noise exposure and will do so prior to the exposed person being aware.

Figure 13 displays a series of audiograms reflecting progression of noise-induced hearing loss. Note the characteristic high-frequency notch which both deepens and widens as that loss progresses with repeated exposure. The notch is a reliable indication of both noise exposure and susceptibility to that particular exposure. Since the initial stage of exposure progresses without the worker being aware, the audiogram provides early warning to that worker. Audiograms displaying the notch typical of noise-induced hearing loss are labelled as Early Loss Index (ELI). Those audiograms where HTL's do not exceed 25 dB and where no significant notches exist are labelled as normal for occupational hearing purposes. Those audiograms showing a hearing loss from which noise exposure cannot be readily identified, or where other factors appear to be involved independent of or in addition to noise exposure, are placed into a medically questionable category. Workers with medically questionable results should consult their physician.

Occupational hearing testing is not sensitive to the more subtle types of auditory disease. The purpose of the program is occupational health not public health. If a disease is progressive, however, its existence will likely be identified on a subsequent test due to the resultant shift in hearing. Occupational hearing testing is quite sensitive to noise susceptibility - its primary purpose. Noise susceptibility varies among workers. Some workers can take a much higher exposure than others, but there is no means of identifying susceptibility until after the fact. Consequently, all workers must be protected and tested. The primary purpose of audiometry or occupational hearing testing in the workplace is to monitor the effectiveness of

hearing protection. By periodic testing, problems with the protection program can be identified prior to a worker's hearing becoming impaired.

The range of frequencies being tested is that important for the reception of speech, or more importantly the accurate discrimination of speech. Some loss of hearing can be tolerated from 3,000 Hz to 8,000 Hz without adversely affecting speech discrimination although this is a point of debate. Such debate is more academic than real, however. If the hearing loss progresses to the point where frequencies between 500 Hz to 3,000 Hz are being affected, that person will begin to experience difficulty in speech communication. When this occurs, a person is said to have a hearing handicap or impairment as opposed to a loss of auditory sensitivity (hearing loss) which does not significantly affect speech communication. Therefore, the objective of an occupational hearing conservation program is to protect a person's ability to communicate.

Another feature of audiometry, and perhaps the most important feature, is worker education. Studies in England have shown, what has long been casually observed, that workers in audiometric programs accept hearing protection better than those not undergoing audiometry. To be effective, the audiometry must be followed up with individual post-test counselling. Also, random scheduling of testing is more effective than precise scheduling. In other words, a routine schedule implies a routine program and hence reduces its effectiveness. By providing the worker with individual attention and counselling he begins to learn about hearing, about noise and its affect, and particularly how it affects him. This education will then carry over not only in the work situation but to everday life as well. Such an approach is far better than "here's an earplug, wear it in noise". Post-test counselling in industry is frequently the only opportunity management has to educate the worker about noise, proper use of hearing protectors, and the reasoning behind their use.

Audiometry is still useful, even if an administrative control program is in effect, that is, to rotate regarding impact or impulse noise was reflected workers so that their allowable dose of noise is not exceeded, hence reducing the need for hearing protectors. Audiometry tells management and the worker if the administrative controls are adequate.

Audiometric programs identify to both employers and workers the effectiveness of a given protection program either administrative or prosthetic, and help the employers promote acceptance of hearing protection. In summary, occupational hearing testing accomplishes:

1. provides both workers and employers with a record of the workers hearing throughout their exposure period within a given company;
2. monitors the effectiveness of hearing protection programs;
3. is an excellent educational tool;
4. may be the first step toward identifying a medically or rehabilitatively correctable hearing loss.

LEGISLATION

ALBERTA NOISE REGULATIONS

Alberta has long recognized noise as an occupational health hazard, and taken steps to establish minimum standards in an effort to protect worker's hearing. Noise regulations were present in Alberta as early as 1957 and were subsequently amended in 1966. The amended version stressed reduction of hazardous noise levels or isolation of workers from those noise levels. If these methods were not feasible, hearing protection was to be supplied to the worker. In addition, the Provincial Board of Health could require audiometric testing. Sound pressure levels were established at octave bands. The amount of allowable exposure was calculated from contours drawn across the octaves shown on Figure 14.

New regulations went into effect in 1971 and were amended later that year. The 5 dB doubling scale for damage-risk criteria and the A-weighted method of measurement were brought into effect. Concern

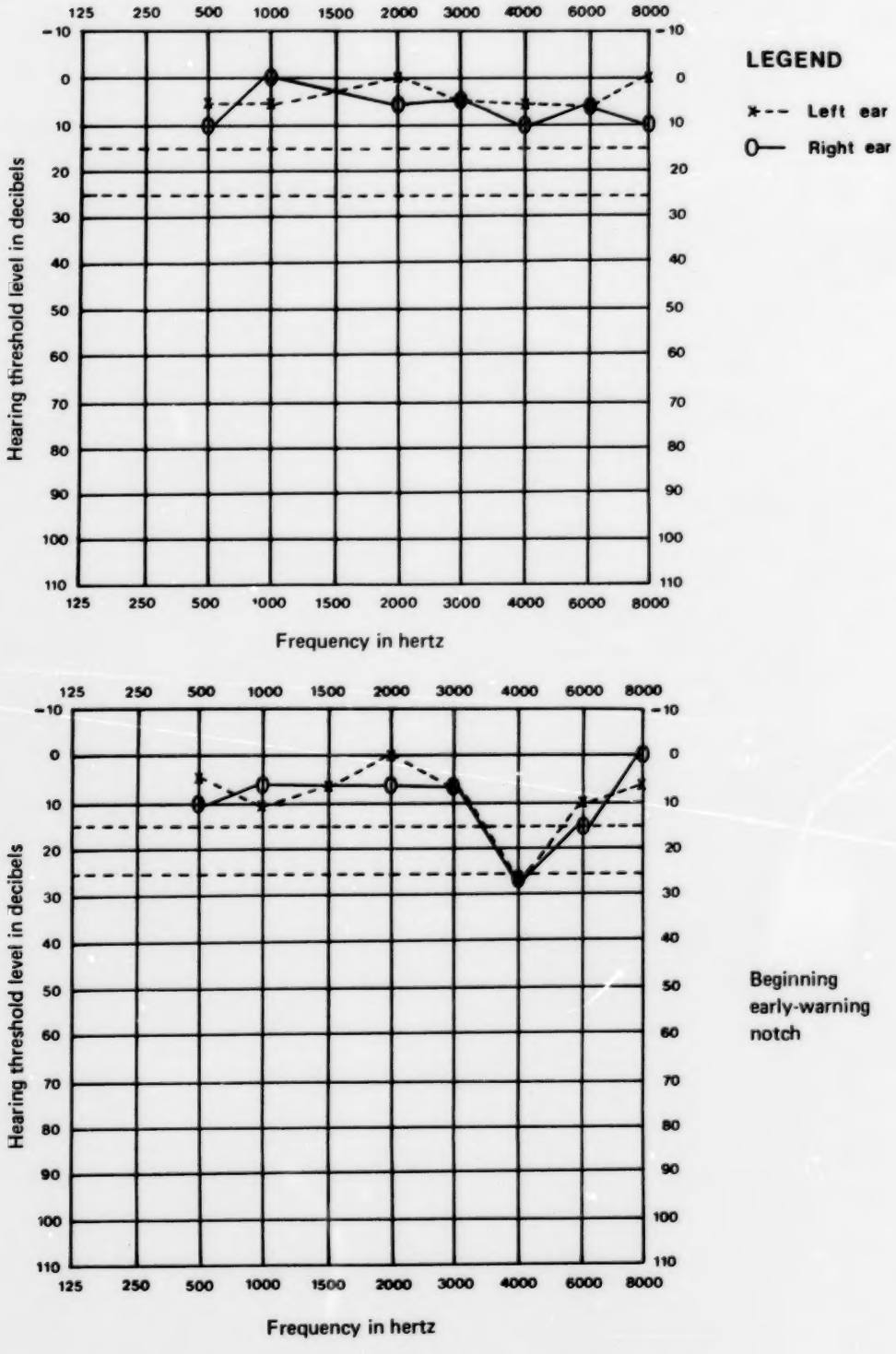

125 250 500 1000 1500 2000 3000 4000 6000 8000
-10 0 10 20 30 40 50 60 70 80 90 100 110
Hearing threshold level in decibels
Frequency in hertz
LEGEND
Left ear
Right ear
Beginning early-warning notch

FIGURE 13: Audiogram showing progression of noise - induced hearing loss.

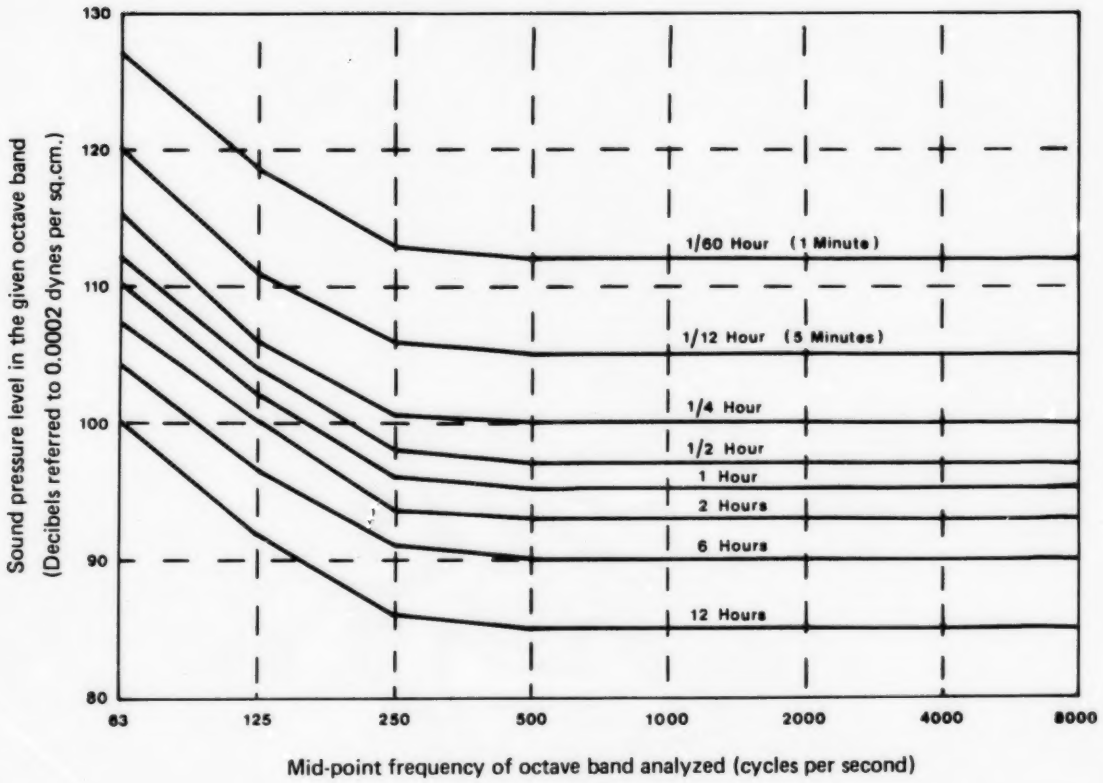


FIGURE 14: Contours showing the maximum sound pressure levels to which persons may be exposed each day for the given time periods.

Source: **Provincial Board of Health Regulations 1966. Division 29.**

by the establishment of a maximum unprotected exposure of 140 dB peak SPL. Measurement for impact noise was taken utilizing the C scale on the sound level meter with fast response. The regulation was amended twice in 1973. The initial amendment greatly expanded the concept of audiometry. The second amendment limited an eight-hour exposure to 85 dBA as opposed to the more traditional 90 dBA. Alberta Regulation 30/71 with its four amendments is the present noise regulation in the province.

Alberta Regulation 30/71 is under Division 29 of the Public Health Act. This regulation was brought into effect at a time when responsibility for its administration rested with the Division of Industrial Health Services of the then Department of Health. When the present Division of Occupational Health and Safety was formed in the Department of Labour in 1975, responsibilities for Division 29 were transferred there. In April 1979, this Division was transferred to the present Department of Workers' Health, Safety and Compensation.

At the end of 1973, Division 29 was a model document. It was one of the world's first pieces of noise legislation to embody the training of audiometric technicians, use of the A-weighted network, laboratory calibration of audiometers, and sound standards for audiometric testing. It is still the only legislation in North America with an 85 dBA exposure limit for an eight-hour period.

Despite the landmarks established by this legislation, technology and circumstances have changed as the province has developed. Consequently, revisions to Division 29 have been proposed. Among the recommendations within the proposal are a better-specified schedule of audiometry, provision of updating courses for audiometric technicians when necessary, post-test counselling of workers when test results are medically questionable or display large shifts in hearing from earlier tests, and review of audiograms by experienced professionals when test results are medically questionable. In addition, engineering controls are re-emphasized and definite exposure limits to impact noise are established. Impact or impulse noise must be measured with an impulse noise meter in lieu of the standard sound level meter. Also, a brief annual report is required from industry to enable the Divison to better monitor the effects of hearing conservation programs.

Generally, the proposed revisions more clearly outline to an employer what is required in a hearing conservation program. It should be realized that a regulation is a minimum standard geared to those industries that are least able to provide programs. Regulations are not ideal standards. It is of little benefit to promote ideal standards that are impossible for industry to comply with, or are unenforceable.

3 dB VERSUS 5 dB

Closely related to development of legislation are two debates that involve acoustical experts, but have a profound impact on hearing conservation practices. First is the debate on the doubling scale utilized as damage-risk criteria. Damage-risk criteria (DRC) is a level of exposure considered safe for the majority of people yet still allows industry to function. Since susceptibility varies among people, particularly at lower intensities, an average exposure that would protect most people is all that is practical. Table 2 is an example of a 5 dB doubling scale. Each instance the exposure time is doubled, the person is allowed 5 dB less intensity if unprotected, that is, 95 dBA for two hours, 90 dBA for 4 hours, 85 dBA for 8 hours, and so on. Another method is 3 dB doubling which is currently a regulation in British Columbia.

TABLE 2
5 dB Doubling Scale of
Permissible Noise Exposure Levels

Noise Exposure Duration per Day/Hours	Permissible Noise Exposure Sound Level (dBA slow response)
16	80
8	85
4	90
2	95
1	100
1/2	105
1/4	110
1/8	115

Source: Alberta Regulation 30/71 (as amended 1973).

Damage-risk criteria was established basically through studies of temporary threshold shift (TTS). Whereas it has been recognized that TTS may not be directly related to permanent threshold shift (PTS), it was felt that the magnitude of growth and recovery of TTS provided clues as to PTS. The 5 dB doubling technique has largely developed from TTS study. The 3 dB doubling method is closely aligned to the equal energy theory, that is, equal amounts of A-weighted energy cause equal amounts of hearing loss. Mathematical models developed by British researchers, supported by population survey studies, tend to indicate that the equal energy principal is a better predictor of PTS than is TTS. Also, the 3 dB doubling concept is more protective at higher intensities than is the case for 5 dB doubling. Adherents to the equal energy theory have argued

consistency of that exposure which causes noise-induced hearing loss. Isolated traumatic exposure resulting in sudden noticeable hearing loss is fairly infrequent within industry and is more typical of the military environment. Hearing loss due to a single traumatic exposure, such as an explosion, may recover partially or entirely. Hearing loss due to repeated exposures at lower intensities, as is typical in industry, is more gradual, less noticeable, and irreversible.

PROBLEMS OF HEARING CONSERVATION WITHIN THE WORKPLACE

ECONOMIC ASPECTS

A personal protection program can be expensive. Providing a worker with adequate hearing protection throughout the course of the year may cost an employer in excess of fifty dollars. Further, audiometric testing is estimated to cost twenty dollars per worker. This may be a conservative estimate. Equipment must be purchased for an in-house program, and testing personnel must attend a training course. Workers lose time for testing. Some workers must be transferred long distances to the test site. If test results are not reliable or are questionable, the procedure must be repeated. Some companies arrange for workers to have time off for doctor visits in cases of medically questionable test findings. This results in more lost time. Many workers receive a baseline test then terminate their employment with the company. Although the workers, in this case, receive some benefit from the test, the benefit to the company is negligible. On the other hand, the engineering controls are even more expensive, particularly in the short term.

PROBLEMS FROM A MANAGEMENT POINT OF VIEW

Aside from the economic considerations, the manager frequently asks why he should be held accountable for a worker's hearing problem when the job occupies only about fifteen percent of the worker's lifetime. The manager reasons that unlimited and unregulated noise exposure exists off the work site, that is, the remaining eighty-five percent of the worker's lifetime, the consequences for which he is held liable under Workers' Compensation. Also, many workers are in effective hearing conservation programs in one job, but hold another noisy job where no program exists. This apparently occurs in some compressed work-week situations and of course 'moonlighting' has long been a common practice. The biggest offender of all, in the eyes of management, is music, such as found in discos, cabarets, home stereo headsets, and so on.

Another problem facing management in Alberta is a skilled labour shortage. Argue with a skilled worker over an earplug and he will simply go down the road to another manager who is more benign about such matters. The conscientious manager must then try to find a replacement.

Related again to economic considerations are those industries characterized by very high labour turnover and operations in remote areas. Consider a drilling company with a manning roster of three hundred people that actually may employ over eight hundred in the course of a year. Audiometry becomes economically unfeasible and administratively impossible under such circumstances. As stated earlier, much of the impetus of the program is lost without the monitoring component. It appears, at least on the surface, that the protection program is suited to those industries with a fixed location, medical staff, virtually no worker turnover, and of course money.

PROBLEMS FROM A WORKER'S POINT OF VIEW

Occasionally, workers feel that audiometric results may be used as a tool for their dismissal, or that results, in the case of a job application, will prohibit them from being hired altogether. It should be realized that hearing conservation is not the only program being promoted within industry, and workers may become annoyed with other test requirements.

On the other side of the coin, many workers in Alberta are employed in very small operations that rarely encounter personnel from the Division of Occupational Health and Safety. What assurances exist that these workers are adequately protected?

SOLUTIONS

Remote locations and personnel turnover appear to be the major problems of promoting occupational hearing conservation in Alberta today. A worker must remain in a program long enough to be monitored. Although individual benefits accrue to the worker when tested initially, they tell management little about the protective program. The worker will soon grow weary of taking three or four baseline tests a year depending upon the number of job transfers he takes. Regulations in Alberta make allowance for this situation. It is expected, however, that hearing protection be provided for the worker, that he wear it while employed, and that those workers who are stable be in audiometric test programs. By establishing an effective core program for the stable work force within an industry, a positive attitude toward hearing conservation will develop, and influence the transient worker. His hearing, therefore, will be better protected than if absolutely nothing is done.

Over the long term, it is a good investment for a company to have their own testing program. The capital outlay for equipment is relatively inexpensive. The program becomes more flexible and lost-time costs can be effectively reduced. Personnel involved with in-house programs are usually on-site and can follow through in the enforcement of hearing-protection use. Those companies that are very small, or widespread, and cannot afford audiometric facilities, must look to mobile contracting services. In remote areas, employers should jointly share the costs of an in-house effort or a mobile service. Collapsible test booths can be obtained, necessitating use of only a pick-up truck instead of a mobile van. Also, Alberta sound-room standards are liberal enough to allow testing in untreated rooms. For example, recreational rooms at oil well drilling campsites have been found to be adequate to conduct audiometric testing. The drilling industry recently has made a significant effort toward establishing hearing conservation programs.

Industries characterized by transient labour usually find that members of the work force remain within the industry but simply move from employer to employer. This raises the possibility of an industrial program rather than a company program. Such centralized effort has merit, but there are many problems with its implementation. Some people have suggested a totally government-run program. Such a massive effort on a provincial scale is not considered feasible at this time, and would not solve all problems in any case. Unfortunately, some segments of the private sector have expended much energy in articulating why they cannot promote such an effort, rather than exploring ways and means to implement what can be accomplished.

With respect to off-the-job noise exposure, it has long been recognized that workers in noisy environments have poorer hearing than those who work in quiet surroundings. People tend to do three activities consistently, eat, sleep, and work. Only work has the potential to be noisy (hazardous noise, that is). Consistent overexposure causes hearing loss. If workers are better protected on the job, it is less likely that intermittent recreational pursuits will cause noise exposure damage of significance. This particularly applies to music. Although exposure to music can cause TTS and has high dBA value, it has acoustical qualities making it much less hazardous than exposure to a like amount of occupational noise. In any case, a consistent audiometric program will indicate shifts in hearing due to noise. If it is obvious that the loss is not occurring on-site, then it must be caused off the site. This information is more useful to the manager than no information at all.

Worker resistance to hearing conservation will decline as it becomes more established within the province, and as more companies become involved. This should alleviate the short-term difficulty of retaining skilled labour due to enforcement of health and safety programs. The public at large will

have a better understanding of hearing tests, consequently workers will not fear audiometric results. A worker with an Early Loss Index who applys for a job is not necessarily a risk to the employer at all. The test results simply show that the worker was sensitive to a prior exposure which may be entirely different from the one in which he is seeking to work. If a manager truly desires to dismiss a worker, he has an array of tools at his disposal and certainly does not need to rely on a simple audiogram. Certain occupations, such as policemen, firemen, pilots, and so on, require acceptable levels of hearing. The reasons for this are understandable. In any case, experience with hearing testing shows that workers and the public in general are most eager to have their hearing tested and have a very deep interest in the topic.

Employers have noticed that the cost of hearing-loss claims is much lower in Alberta than compensation awarded for other disabilities. Some of this disparity may be due to Alberta having a young, mobile work force, and with older workers being unaware of noise-induced hearing loss or compensation for it. Others simply may not be inclined to apply for hearing-loss claims. The predominantly young work force today may not be as mobile in the future and will certainly not always be young. They will, however, be better educated about hearing and compensation for its loss. If industry does not take steps, today, to control exposure to noise, it may find in twenty-five years that the cost of noise is indeed high.

Audiometry does not in itself solve all problems in administering hearing conservation programs, nor can expenses be reduced to a level that is considered cheap. By purchasing more cost-effective hearing protectors, with effective and shared use of mobile test contracting or in-house facilities, with more careful documentation as to who is overexposed and consequently who really needs to be in the program, and by limiting audiometry to the stable work force, much can be done to reduce costs and make the program manageable. Perhaps a well-enforced, slightly expensive, personal protection program will serve to motivate industry to reduce noise levels so that these programs are no longer necessary.

One final comment on problems, and this relates more to government itself. There are numerous small businesses throughout Alberta that employ a large percentage of the provincial work force. Adequate enforcement of regulations in this situation is most difficult. It is felt, however, that the prime noise-generating processes within the province are well recognized and monitored at this time. Most of the industries concerned, with one or two expections, have taken steps to implement effective hearing conservation programs. Also, these industries tend to have a more stable work force than the smaller businesses, such as a car wash. It is important, however, that enforcement of regulations be uniform across industry. It is unfair for one company to cooperate, in terms of operational costs, if a competing company does not comply. Industry, government, and workers all have responsibilities in health and safety, and hearing conservation is no expection.

HEARING CONSERVATION RESOURCES

A worker concerned about hearing conservation or personal protection from the effects of occupational noise has a variety of options to exercise. Many larger companies provide employees with occupational health services, of which hearing conservation is a part. The plant health services employ an occupational health nurse and perhaps a physician, at least on a consulting basis. In smaller industries, the hearing conservation effort may be administered by safety or first-aid personnel who report to the personnel manager or an industrial loss-control coordinator. The latter may apply as well to the larger organizations as the loss-control coordinator is responsible for fire, safety, health, and security.

Many employers have established joint worksite health and safety committees. These committees are composed of worker and management representatives from the worksite, meeting to formulate

advice to management on predominantly safety matters. They will, however, advise management on occupational health concerns brought to their attention.

The concerned worker should first exhaust all avenues within his place of employment. If his concerns are not satisfied or resolved, the organized worker can approach his union. The labour movement has developed a commendable interest in occupational health and safety over the past few years. Finally, the worker may contact Occupational Hygiene or Medical Services Branches of the Division of Occupational Health and Safety. Occupational Hygiene should be contacted if the concern is about noise level, exposure time, and so on. Medical Services Branch should be contacted if the concern is about hearing protection, hearing loss, or the audiometric program.